SLAC-116 UC-28 (SR)

TWO-MILE ACCELERATOR PROJECT

1 October to 31 December 1969

Quarterly Status Report

STANFORD LINEAR ACCELERATOR CENTER STANFORD UNIVERSITY Stanford, California

PREPARED FOR THE U. S. ATOMIC ENERGY COMMISSION UNDER CONTRACT NO. AT(04-3)-400 AND CONTRACT NO. AT(04-3)-515

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ABSTRACT

A status report on the Stanford Linear Accelerator Project covering the period October 1, 1969 to December 31, 1969 is presented. Topics included are accelerator and research area operations, accelerator and research area equipment development, and physics research equipment development.

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SLAC-1,	1 April - 30 June 1962.
SLAC-8,	1 July – 30 September 1962.
SLAC-10,	1 October - 30 December 1962.
SLAC-16,	1 January - 31 March 1963.
SLAC-18,	1 April - 30 June 1963.
SLAC-23,	1 July - 30 September 1963.
SLAC-27,	1 October - 31 December 1963.
SLAC-30,	1 January - 31 March 1964.
SLAC-32,	1 April - 30 June 1964.
SLAC-34,	1 July - 30 September 1964.
SLAC-42,	1 October - 31 December 1964.
SLAC-45,	1 January - 31 March 1965.
SLAC-48,	1 April - 30 June 1965.
SLAC-53,	1 July – 30 September 1965.
SLAC-59,	1 October - 31 December 1965.
SLAC-65,	1 January - 31 March 1966.
SLAC-69,	1 April - 30 June 1969.
SLAC-71,	1 July - 30 September 1966.
SLAC-73,	1 October - 31 December 1966.
SLAC-80,	1 January - 30 June 1967.
SLAC-85,	1 July – 30 September 1967.
SLAC-87,	1 October - 31 December 1967.
SLAC-89,	1 January - 31 March 1968.
SLAC-90,	1 April - 30 June 1968.
SLAC-93,	1 July - 30 September 1968.
SLAC-98,	1 October - 31 December 1968.
SLAC-105,	1 January - 31 March 1969.
SLAC-110,	1 April - 30 June 1969.
SLAC-112,	1 July - 30 September 1969.

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INTRODUCTION

This is the thirtieth Quarterly Status Report of work under AEC Contract AT(04-3)-400 and the twenty-fourth Quarterly Status Report of work under AEC Contract AT(04-3)-515, both held by Stanford University. The period covered by this report is from October 1, 1969 to December 31, 1969. Contract AT(04-3)-400 provides for the construction of the Stanford Linear Accelerator Center (SLAC), a laboratory that has as its chief instrument a two-mile-long electron accelerator. Construction of the Center began in July 1962. The principal beam parameters of the accelerator in its initial operating phase are a maximum beam energy of 20 GeV, and an average beam current of 30 micro-amperes (at 10% beam loading). The electron beam was first activated in May 1966. On April 27, 1969, a beam energy of 21.5 GeV was achieved. Beam currents up to 70 milliamperes peak have been obtained.

The terms of Contract AT(04-3)-400 provide for a fully operable accelerator and for sufficient equipment to measure and control the principal parameters of the electron beam; in addition, provision is made for an initial complement of general-use research equipment with which it is possible to perform certain exploratory studies, such as measurement of the intensity and energy distribution of various secondary-particle beams.

Contract AT(04-3)-515, which went into effect January 1, 1964, provided support for the various activities at SLAC that were necessary in order to prepare for the research program which is being carried out with the two-mile accelerator, and also provides for the continuing operation of the Center after completion of construction. Among the principal activities covered in the scope of Contract AT(04-3)-515 are theoretical physics studies, experiments performed by the SLAC staff at other accelerators, research-equipment development programs (such as particle separators, specialized magnets, bubble chambers, etc.), and research into advanced accelerator technology.

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I. ACCELERATOR OPERATIONS

Manned Hours	Oct.	Nov.	Dec.	Quarter
Physics Beam Hours ⁽¹⁾				
Machine Physics	37	22	16	75
Particle Physics	<u>513</u>	_10	472	995
Total Physics Beam Hours	550	32	488	1,070
Non-Physics Hours				
Scheduled Downtime	16	16		32
Unscheduled Downtime Due to				
Equipment Failure	30	3	17	50
All Other (Machine Tune-Up, etc.)	52	13	58	123
Total Non-Physics Hours	98	32		205
TOTAL MANNED HOURS	64 8	64	563	1,275

Experimental Hours⁽²⁾ в.

Operating Hours

Α.

Particle Physics 1.

(3)	Sched. Hrs. Electronic	Electronic Experimental Hrs.		%	Actual Bubble	Actual Test And	Total Experimental	
Beam Line	Experiments (a)	Actual Hours (b)	(4) Charged Hours	$\left(\frac{b}{a}\right)$	Chamber Hours	Checkout Hours	Actual Hours	Charged Hours
Α	979	658	710	67.2		58	716	76 8
в _N						360	360	360
B _C	35	29	8	27.6	90	235	354	333
^B S								
C	326	260	198	79.8	236	1,387	1,883	1,821
Total	1,340	947	916	70.7	326	2,040	3,313	3,282
2. Machine Physics						79	79	
TOTAL EXPERIMENTAL HOURS							2 202	2 261

- (1) Number of hours accelerator is run with one or more beams excluding accelerator beam tune-up and other non-physics beam time.
- (2) Number of hours an experiment is run including actual beam hours and beam downtime "normal to the experiment."
- (3) Refer to Fig. 1 for beam line location.
- (4) Total number of experimental hours actually run multiplied by factor (F), where $F = \frac{Average repetition rate}{100 mm}$ (F maximum = 1.5 even if calculated amount exceeds 180 pps this value). This product represents the hours charged to the experiment.

3,392

3,361

C.	Overall	Experi	imental	Prog	ram	Status
	and an an an an an an an an					

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1.	Electronic Experiments				
	Approved research hours at beginning	ng of quart	er	4,106	
	Hours charged during the quarter			916	
	New hours approved during the quar	·ter		483	
	Approved hours remaining at end of	quarter	•	3,673	
2.	Bubble Chamber Experiments		<u>40'' 1</u>	<u>BC 82</u>	<u>'' BC</u>
	Approved pictures at beginning of qu	larter	956 F	ζ 1,	550 K
	Pictures taken during the quarter		193 F	ζ	441 K
	New pictures approved during the qu	uarter	<u>93 F</u>	<u> </u>	<u>,600 K</u>
	Approved pictures remaining at end	of quarter	856 F	ς 2,	709 K
D.	Beam Intensity	Oct.	Nov.	Dec.	Quarter
	Peak	52 mA	77.5 mA	50 mA	77.5 mA
	Average	5.2 μA	5.2 µA	4.8 μΑ	5.1 μΑ
E.	Klystron Experience				
	Total Klystron Hours	154,185	13,012	136,449	303,646
	Number of Klystron Failures	5	0	5	10
F.	Data Analysis				
	Spark Chamber Events Measured	36,663	31,821	13,660	82,144
	Bubble Chamber Events Measured	18,122	14,430	20,754	53,306
G.	Computer Operations				
Ma	nned Hours				
	Computation Hours	109	125	137	371
	SLAC Facility Group	389	409	422	1,220
	User Groups	498	534	559	1,591
				4	
	Non-Computation Hours				
	Scheduled Maintenance	103	105	87	295
	Scheduled Modifications	25	23	28	76
	Unscheduled Downtime and Reruns	25	42	16	83
	Idle Time	12	15	5	32
	Utility Failure	50			50
	Total Non-Computation Hours	215	185	136	536
	TOTAL MANNED HOURS	713	719	695	2,127

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H. Special Operating Features

1. Positrons

Using the fixed "wheel" as a source, interlaced positrons and electrons were delivered for 12 hours of checkout and 128 hours of experimental use in October. Positrons were not required for the balance of the quarter.

2. Beam Knockout

The beam knockout was used for 733 hours at 10 and 40 MHz, for 5 hours at 5 and 40 MHz and for 11 hours at 40 MHz for a total of 749 hours during the quarter.

3. Power Supplies

The 3.4 MW power supply was run for a total of 550 hours with the analyzer magnet in beam line 11.

The 5.0 MW power supply was run for a total of 5 hours with the 54" spark chamber.

The 5.8 MW power supply was run for a total of 549 hours with the two meter spark chamber.

The motor generator facility was run for 150 hours with the 40" bubble chamber and for 333 hours with the 82" bubble chamber for a total of 483 hours for the quarter.

II. RESEARCH AREA OPERATIONS AND DEVELOPMENT

A. General Beam Switchyard and Research Area Developments

Major installation effort was expended on E-40, * E-53, and E-21c. There were many minor beam changes and building moves and a large addition of shielding to beam line 13 for E-48.

It was discovered that the B-switching magnets PM30 and PM31 were very noisy and that their end plates were very hot. Closer examination disclosed that the end laminations had worked loose and were vibrating, scraping the coils and becoming very hot in the pulsed magnetic field. The magnets were removed, the coils were repotted, the cores were reglued and reinforced with a NEMA G-10 clamp, and the magnets were reassembled and reinstalled.

For the first time at SLAC, four liquid hydrogen targets were in use simultaneously during December, serving Experiments E-41, E-40, E-53, E-42, E-45, and E-50a. (The last three are spectrometer experiments using the same target.)

The 5.0 MW power supply was accepted and put into service. Work continued on splitting the 5.8 MW power supply so that it can be used as two smaller power supplies if necessary.

The six new 400 kW power supplies which have been undergoing tests since June were finally accepted.

B. Data Assembly Building Control Room Improvement

During the November shutdown installation of equipment in the East Console in Data Assembly Building (DAB) was completed, and except for a few controls, independent beam operation is now possible from both the East and West Consoles. The major systems installed during this period included pulsed steering, dc steering and magnet control interlock status displays and video monitoring. Other equipment installed in DAB during November included a nuclear magnetic resonance system with probes in magnets B11 and B12, and a control panel for the new, sixposition target TC-30. A prototype errant beam detector was also installed. The detector receives inputs from three toroids, one in each beam line, and turns off all beams if a beam is detected in a beam line for which there is no beam pattern. Hardware and programming effort continued on the SDS-925 computer in DAB.

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See Table I for titles of experiments.

The computer system is now capable of setting B-bend and the B-side quads in addition to the previous capability of setting A-bend and displaying interlock status. The new SDS drum (162K words) was installed.

C. Laser Facility

Recent improvements in the C-beam laser facility now permit easy optimization of the photon yield. A short (two-shift) run demonstrated an improvement of about a factor of two over previous yields. Tests with Second Harmonic Generation have indicated that about 25% of the laser energy can be converted. New lenses and mirrors have been installed and blue light has been delivered to the interaction region.

D. Hydrogen Bubble Chamber Operations Group

The 40" bubble chamber took about 200 thousand pictures before a bellows leak, which had developed early in the run, became so large that it was impossible to continue. The chamber was shut down and pulled apart for installation of a new bellows. The bellows to be put in will be of a different type than had been used previously and should be much more satisfactory. Installation should be completed in January and at that time the chamber will be cooled and filled with neon to test a new neon-hydrogen target system that has been under construction for the last several months.

The 82" hydrogen bubble chamber was cooled down the middle of November and was filled with hydrogen and tested prior to the December run. It was expanded 1,119,685 times during December. Data were obtained for BC-5, BC-11, and BC-14.

E. Spectrometer Facilities Group

Experiment 47 (π^+ photoproduction), which used the Berkeley Polarized Target setup for E-29, was completed during October. All of the equipment was removed in the last days of the month and shipped back to Berkeley.

The beam line hydrogen target and spectrometer configuration and instrumentation was set up for running E-21c and checkout runs for E-42, E-45, and E-50 during December.

During this period the Spectrometer Group completed four movable carriages: three for E-21c and E-50 and one for E-42. Another shielding carriage will be required next spring for E-42. All of the carriages can be remotely positioned,

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with digital angle readout. In addition, the three carriages for E-21c and E-50 are capable of being elevated remotely, with readout.

F. Description and Status of Approved Experiments

Figure 1 is a research area plan drawing showing the location of the various experiments. Figure 2 shows the tentative long-range schedule. Table 1 is a list of presently approved high energy physics experiments. The right hand column of Table 1 gives the status and activity of each experiment during the period.

The prime users of the accelerator during October were: D-6 (Charpak chamber tests), T-11 (beam tests for E-40), CE-41, E-47, CE-48, CE-53, and BC-19.

During the 3 October 1969 meeting of the Program Advisory Committee, Experiments BC-11 and BC-14 were granted extensions.

The accelerator was shut down during November. The prime users during December were D-6, T-11, E-21c, CE-40, E-41, CE-42, CE-45, CE-48, CE-50a, E-52, CE-53, BC-5, BC-11, and BC-14.

During the 12-13 December 1969 meeting of the Program Advisory Committee BC-30 and E-60 were approved and BC-11 and BC-13 were granted extensions. BC-33 was also approved by the Director for an engineering run.

1. Status of Running Experiments

D-6 – Charpak Wire Chamber Tests

D-6 ran in beam line 6 in October and December. The following summarizes the results of the tests. Several mixtures of argon, helium, isobutane, and isobutylene were tried. The most satisfactory one found was 80% He, 20% isobutylene. The maximum efficiency measured was $93.5 \pm 1.2\%$ with a 300-nsec resolving time and $90.9 \pm 1.6\%$ with a 50-nsec resolving time. Efficiencies in the range of 85-90% were routinely obtained. The timing spectra are approximately gaussian with 50-nsec width at the base. The leading edge of this spectrum ("early" events) occurs ~ 25 nsec before the output of a 6073 phototube.

E-21c – Measurements on the Photoproduction of π^{0} , η , ρ^{0} , ω and ϕ Mesons

at Small Momentum Transfer t and Photon Energies up to 18 GeV and a Search for Mesons of Other Masses

This experiment was the prime experiment in end station A during December. The experimenters finished the study of the reaction $\gamma p \rightarrow \pi^0 p$ for t-values in the range from -.1 GeV² to -.4 GeV² and 5 photon energies between 4 GeV and

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18 GeV. The experiment was performed by measuring the recoil proton yield as a function of missing mass using the SLAC 1.6 GeV/c spectrometer. To reach the small t-values a gaseous hydrogen target with about one-seventh of the density of a liquid target was used successfully for the first time. This target reduces the amount of material which the proton must pass through before reaching the detector system by about an order of magnitude. In addition to the π^0 measurements some more data were also collected for the reactions

$$\gamma p \rightarrow \eta p$$
$$\gamma p \rightarrow \rho^{o} p$$
$$\gamma p \rightarrow \phi p$$

The data will be used to determine if the reaction is dominated by a fixed pole or by exchange of the $\omega(\rho)$ - trajectory. In the former case the energy dependence will be S⁻²; for the ω -exchange an energy dependence of the form S^{2 α (t)-2} is expected with $\alpha = .5 + .9$ t.

CE-40 – <u>High Statistics Study of the Production of Charged ρ^{\pm} Mesons, Neutral</u> ρ^{o} Mesons, f^o Mesons and Nucleon Isobars by Pions

This experiment is to measure with high statistics the differential cross section and when appropriate the density matrix for production of ρ and f mesons and nucleon isobars by pions. The experiment is in the early stages of a check and a new π beam in end station B was developed for this experiment. The beam line was complete and checkout of the optics, background and steering was performed. The first spark chamber and the first 16-element scintillation counter hodoscope for the experiment were installed and tested with the beam. Installation and testing of equipment for the experiment, its associated electronics and on-line computer proceeded. The liquid hydrogen target was available for part of the period and was used in the counter and spark chamber tests.

E-41 – Rho Production by Pions - A Test of Vector Dominance

This experiment is studying the reaction $\pi^- p \rightarrow \rho^0 N$ and related reactions using a wire spark chamber spectrometer and a π beam in beam line 11 in the C-beam area.

The October running period was devoted to checkout of apparatus required for the experiment. All counters were plateaued and timed. Proper operating conditions were determined for the large Cerenkov counter and the beam Cerenkov counter. The electron-shower counter and the μ -range telescope, both used for measurements of beam contamination, were also brought into operation.

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Considerable work was done on reducing background at the apparatus. This background was determined to come from two sources, partly from the "C" beam target rooms and from beam line 11 itself. By proper placing of shielding near the target room, the first source of background was reduced by a factor of approximately 5. The background coming from beam line 11 was reduced by about 40 by collimation and large masses of shielding near the end of the beam.

During December the wire spark chamber was checked out, together with the π^- beam at 8, 11 and 15 BeV/c. The beam and wire chamber systems worked well. Ten days were spent collecting data at 15 BeV/c incident π^- momentum. During this run ~2500 ρ^{0} n events, ~500 f⁰ (both resonant states decaying into 2π), some 600 A₂ mesons decaying into K⁺K⁻, and ~1500 (A₁+A₂) meson decays in 3 π were collected. The experiment will continue the program of data collection in January. The proposed aims of (a) testing vector dominance by comparison with the reaction $\gamma p \rightarrow \pi^+ n$, (b) looking for possible structure around the A₂ meson in K \overline{K} decay, (c) surveying the meson resonance production, look as though they will be achieved.

E-42 - Photon-Proton Scattering at Forward Angles

A one-day test run in December for this experiment met most of the objectives for the run; namely to study sources of backgrounds for the experiment. A simple set of trigger counters was set up as described in the E-42 proposal, and a spark chamber inside the pair spectrometer concrete hut. The spectrometer was positioned at 1° to the beam line. Counting rates were recorded for various configurations of shielding placed in front of the pair spectrometer magnet and in front of the sweeping magnet. The run demonstrated the need for eliminating muons produced at the gamma beam stopper, and the need for slits and vacuum pipes along the scattered photon path to eliminate electromagnetic background from striking the pole faces of the pair spectrometer magnet.

E-45 – The Measurement of π^+ Photoproduction with Polarized Photons at SLAC

Two 24-hour days of checkout time were used in December to test the feasibility of detecting neutrons using a large scintillator in coincidence with π^+ mesons detected with the 20-GeV spectrometer for possible use as part of the E-45 experiment. The test used a bremsstrahlung beam produced in end station A in the standard way. The effects of absorbers and a sweep magnet in front of the neutron detector were studied. The desired coincidences were observable, provided the spectrometer was set to an energy close to the bremsstrahlung maximum.

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However, in E-45, the spectrometer is set to energies $\sim 3/4$ of the bremsstrahlung maximum. The data obtained, at first hand, indicate that accidental coincidences are very likely too great a problem for such settings. Off-line analysis of the data is presently being performed to see if a cleaner selection of events might possibly improve the situation.

$E-47 - \pi^+$ Photoproduction with a Polarized Target

This experiment, to measure the photoproduction of π^+ mesons from polarized protons, was begun and successfully completed in October. Data were taken at six momentum transfers each, at energies of 16 and 5 GeV. The on-line data analysis indicates that the asymmetry parameter reaches a value of nearly 1 at 16 GeV and is generally fairly large. The off-line analysis has begun. E-48 - Proposal to Measure the ξ Parameter in the Decay $K_{L}^{0} \rightarrow \pi\mu\nu$

During the first test run during October an estimate was made of K^{O} beam intensity and spectrum. The data is not in disagreement with predictions based on the Leith tests. A crude measurement of the spectrum indicates a peak spectrum between 2 and 3 GeV as predicted. The intensity is probably a little higher than anticipated.

Most of the run was spent in trying to reduce background not associated with the K^{O} beam line. A reduction of about a factor of 20 was achieved, but an additional factor of 5 is desirable.

During the December checkout run the experiment concentrated on reducing the background. Additional work was done in timing and plateauing counters and in making the data-logging-and-checking computer operable. Initial results on background using a simple single coincidence trigger logic (desirable to avoid bias) had resulted earlier in a background to K decay ratio of 100 to 1. By the beginning of the December run this was reduced to about 11 to 1. During December, by the use of additional shielding and more effective anticoincidence counters the ratio was reduced to about 3 to 1, a level at which the experiment is feasible. E-50a - Compton Scattering at High Energies from Hydrogen

Accelerator time was used in December to make tests in preparation for this experiment which is a study of proton Compton scattering $\gamma p \rightarrow \gamma p$. In the experiment the main interest is to compare the angular distribution with the angular distributions measured in the vector meson photoproduction of hydrogen. This provides a crucial test of the vector dominance model. In the test run the scattered photon was detected by a shower counter in coincidence with the recoil

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proton as measured by the 1.6 GeV/c spectrometer. The test runs were highly successful and data were collected between $t = -.1 (GeV/c)^2$ and $t = -.3 (GeV/c)^2$ for 4 energies between 6 and 18 GeV. This experiment is the first coincidence experiment done at SLAC using the full primary beam from the accelerator. During the January cycle the experiment will collect data out to larger t-values. E-52 - Determination of γ_{ρ}^2 and the Total ρ N Cross Section from Coherent

-Photoproduction on Deuterium

Test runs were performed in December on the experiment which is designed to study coherent ρ production through the reaction $\gamma d \rightarrow \rho^0 d$. In the tests deuterons were detected using the 1.6 GeV/c spectrometer. From a measurement of the angular distribution one hopes to extract the $\gamma - \rho$ coupling constant as well as the total ρN scattering cross section. The main experimental problem is to identify the deuterons among the much more copiously produced protons. This was achieved using the time-of-flight system, and data were taken at 6-12 and 18 GeV out to t = -.3 (GeV/c)². The data taking will continue in the next accelerator cycle.

CE-53 – Survey of Photon and π^{0} Yields

Several shifts were run at the beginning and end of the October cycle to calibrate and study the shower counters to be used in the experiment. A low pulse rate e⁻ beam (a few e⁻/pulse) from 2 to 15 GeV was used in the C-beam; a few hours were also run at higher pulse rates. The tests were disappointing in that a significantly improved resolution over the original design was not achieved. However, the uniformity of pulse height over the counter area was much improved, enabling the largest possible solid angle in the experiment. In addition, some brief studies of shower diffusion and backscattering were made; these will affect the hodoscope operation.

The beam, counter, and target checkout for E-53 was begun and nearly completed in December. The photon beam performed well; in fact, since the e^- beam spot was smaller than anticipated, the maximum photon flux was more than ten times that aimed for in the design. The shower counters, logic, magnetic tape system, and hydrogen target seem to work properly. Since shower counter energy calibration is of utmost importance and somewhat unstable, a procedure was devised and used to obtain e^{+1} s of known energy, from 4-16 GeV, in the experimental area. This e^+ beam was then used to make several preliminary measurements of γ yields. Because of these results, since the beam capability

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is greater than expected, and since the counters are less rate sensitive than expected, the yield measurements can be extended somewhat — to higher energy (21 GeV) and to smaller cross sections.

BC-11 - <u>A Bubble Chamber Experiment with the Polarized Laser Induced Photon</u> Beam (Extended 10-3-69)

An engineering test with 9.5 GeV photons into the 82" hydrogen bubble chamber was accomplished in December. The ruby laser was used to generate the second harmonic (3471 Å) with about 20% conversion efficiency. The blue light was backscattered off a 19 GeV electron beam to produce the 9.5 GeV photons. 77,851 pictures were taken, sufficient to study the energy spectrum and to determine the yield. Unfortunately, the γ yield was shown to be marginal. BC-5 — A Proposal to Study Many Particle Final States Produced by 12 GeV/c

 π^- Mesons at SLAC

The University of Hawaii Bubble Chamber Physics Group obtained an exposure of 167,743 pictures with 12 GeV/c π^- in December.

BC-14 – Proposal for 7.5 and 13 GeV/c π^+ and π^- Exposures in the SLAC 82" HBC

MIT received some 194,954 pictures of 8.0 GeV/c π^- in December, all taken with the new 35-mm, 3-strip film format. Considerable camera difficulties were experienced. MIT's system with a solid state detector located inside the bubble chamber was further tested. An additional 24,876 pictures were taken during these tests.

BC-19 - γ -d Experiment

This experiment was set up using a 7.5 GeV/c annihilation beam into the 40-inch bubble chamber. About 200 K pictures were taken, completing the authorized run for this experiment.

BC-33 - 300,000 Pictures, 4.5 GeV/c π^- in H₂ 82-Inch Bubble Chamber

This is a proposal for a 300,000 picture exposure in the 82-inch bubble chamber using a 4.5 GeV/c π^- beam. Its principal objectives are to study $\pi\pi$ scattering, to investigate the feasibility and validity of extrapolation techniques for getting cross sections for collisions with virtual particles, and to study ρ production in the reaction $\pi^-p \rightarrow \rho^0$ n with sufficient data and sufficiently broad angular sensitivity so as to determine specific polarization components accurately. This exposure would give about five times more data than any single existing experiment at comparable energies. With improved statistics and an improved extrapolation procedure, and also using data from other $\pi\pi$ charge states, it will eventually be possible to resolve the present ambiguities in the T=0 s-wave phase shift $\boldsymbol{\delta}_0^0$ in this direction.

A second objective is to improve measurements on the density matrix elements of $\pi^- p \rightarrow \rho^0 n$ and $\rho^- p$ at small t. In particular, a high quality measurement of the element ρ_{1-1} is desired so that apparent discrepancies in vector dominance comparisons with photoproduction data can be resolved.

2. Newly Approved Experiments

E-60 - Hyperon Production in K⁻p Interactions

This is a high statistics experiment to investigate the production of hyperon states in K⁻p interactions at 7.0 GeV/c with the SLAC streamer chamber. An estimated 270 events per μ b will be obtained in an exposure of 1.5×10^6 pictures by triggering the streamer chamber to suppress events involving multi- π^0 production, and diffractive K⁻p processes. This will improve the presently available data on hyperon states by an order of magnitude.

In this experiment, detailed studies of the production of hyperon states with particular emphasis on the states with $S \leq -2$ are planned. Some other interesting features are an expected 200 Ω^- events, allowing a study of its properties and search for possible excited Ω states; the possibility of confirming the existence and the J^{P_1} s of some reported Ξ states; and a study of the Y* up to a mass of 3.5 GeV.

BC-30 – Ap Interactions in the Momentum Interval 1 - 5 GeV/c

The purpose of this experiment is to study Λp elastic scattering and the reactions

$$\Lambda \mathbf{p} \to \Lambda \mathbf{p} \pi^+ \pi^-$$
$$\to \Sigma^{\pm} \pi^{\mp} \mathbf{p}$$

in the momentum interval of about 1-5 GeV/c using the 82-inch bubble chamber and to determine the total and differential cross sections for these reactions, as well as polarized information.

For Λ momenta above 1 GeV/c, less than 100 fitted Λ p interaction events exist in the literature. Very little analysis of the physics of these interactions can be made with so few events spread over the range of about 1-5 GeV/c. This experiment will increase the number of events available in this energy range by more than an order of magnitude, making possible much more detailed investigations of energy and angular distributions of Λp interactions. In particular, the following reactions have been found to be readily fittable, in the only previous experiment at this energy, and it is expected that the emphasis of this experiment will be upon analysis of these channels:

$$\Lambda p - \Lambda p$$
 (elastic scattering)

 $\rightarrow p\pi^+\pi^-$ $\rightarrow \Sigma^{\pm}p\pi^{\mp} .$



FIG. 1--Experiment locations.





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TABLE I

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TABLE OF PROGRAMMED EXPERIMENTS

Number	Title	Authors	Date Approved	Status
E-14	Proposal for Testing of Quantum Electro- dynamics by Photoproduction of Asymmetric Muon Pairs	STANFORD (Group A) W. Panofsky, D. H. Coward H. DeStaebler, J. Litt, A. Minten, L. W. Mo, R. E. Taylor <u>MIT</u> J. I. Friedman, H. W. Kendall, L. VanSpeybroeck	11/18/66	d
E-21c	Proposal for Measurements on the Photo- production of π^0 , η , ρ^0 , ω and ϕ Mesons at Small Momentum Transfer t and Photon Energies Up to 18 GeV and a Search for Mesons of Other Masses	STANFORD R. Anderson, D. Gustavson, J. Johnson, R. Prepost, D. Ritson <u>N.E. UNIV.</u> R. Weinstein, <u>M. Gettner</u> <u>CAL TECH</u> R. L. Walker, G. Jones, D. Kreinick, A. V. Tollestrup	3/11/67	h
E-34	Electron-Deuteron Quasi-Elastic Scattering	STANFORD E. Bloom, D. Coward, H. DeStaebler, J. Drees, J. Litt, R. E. Taylor <u>MIT</u> J. Friedman, G. C. Hartmann, H. W. Kendall <u>CAL TECH</u> B. C. Barish	7/2/68	d
E-40	High Statistics Study of the Production of Charged ρ^{\pm} Mesons, Neutral ρ^{o} Mesons, f^{o} Mesons and Nucleon Isobars by Pions	SLAC J.Cox, B.Dieterle, W. Kaune, M.Perl. J.Pratt, J.Tenenbaum, W.Toner, T.Zipf	8/5/68	c,b
E-41	Rho Production by Pions — A Test of Vector Dominance	<u>SLAC</u> F. Bulos, W. Busza, G. Fischer, E. Kluge R. R. Larsen, D. W. G. S. Leith, B. Richter, H. Williams <u>IBM</u> M. Beniston	8/5/68	c,b,a

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Table of Programmed Experiments (cont'd) - 2

Number	Title	Authors	Date Approved	Status
E-42	Photon-Proton Scattering at Forward Angles	SLAC A. Boyarski, F. Bulos, W. Busza, R. Diebold, S. Ecklund, G. Fischer, H. Lynch, B. Richter	3/22/69	c, i
E-43	Velocity of Light Experiment	UCSD G. Masek	12/14/68	a
E-45	Proposal for the Measurement of π^+ Photoproduction with Polarized Photons at SLAC	MIT D. Luckey, L. S. Osborne, R. Schwitters SLAC A. Boyarski, R. Diebold, S. Ecklund, B. Richter	12/14/68	C
E-47	π^+ Photoproduction with a Polarized Target	LRL O.Chamberlain, C.Morehouse T.Powell, P.Robrish, S.Rock, S.Shannon, G.Shapiro, H.Weidsberg <u>SLAC</u> A.Boyarski, R.Diebold, S.Ecklund, Y.Murata, B.Richter	2/8/69	c,a,h
E-48	Proposal to Measure the ξ Parameter in the Decay $K_L^0 \longrightarrow \pi \mu \nu$	BNL D.Hill, R.Palmer, M.Sakitt, N.Samios SLAC D.Fries, F.Liu, R.Mozley, A.Odian, J.Park, W.Swanson, F.Villa	2/8/69	c,b,e
E-49a	Inelastic Electron Scattering From D ₂ and Other Nuclei	SLAC E. Bloom, L. Cottrell, D. Coward, H. DeStaebler, C. Jordan, R. E. Taylor <u>MIT</u> J. Elias, J. I. Friedman, H. W. Kendall, M. Sogard, K. Tsipis, M. Breidenbach, R. Verdier	2/8/69	đ
E-49b	Inelastic Scattering From D_2 and Other Nuclei: Large Angles	SLAC D.Coward MT J.Elias, J.I.Friedman, H.W.Kendall, M.Sogard, K.Tsipis, M.Breidenbach, R.Verdier	8/6/69	d
E-50a	Compton Scattering at High Energies From Hydrogen	SLAC R.Anderson, D.Gustavson, J.Johnson, I.Overman, D.Ritson, B.Wiik <u>HARVARD UNIV</u> . J.Walker <u>NORTHEASTERN UNIV</u> . R.Weinstei	3/22/69 n	c,i

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Table of Programmed Experiments (cont^td) - 3

Number	Title	Authors	Date Approved	Status
E-52	Determination of γ_{ρ}^2 and the Total ρ N Cross Section From Coherent ρ -Photo- production on Deuterium	SLAC R. Anderson, D. Gustavson, J. Johnson, I. Overman, B. H. Wiik <u>NORTHEASTERN UNIV</u> . R. Weinstein	8/6/69	c,i
E-53	Survey of Photon and π^0 Yields	U.C.SANTA BARBARA D.Caldwell, V.Elings, D.Fancher, A.Greenberg, G.Jahn, A.Kaushal, B.Kendall, R.Morrison, F.Murphy, S.Tyler, B.Worster	6/11/69	c,b
E-55	Study of Dalitz Plot for the Decay $K_{L}^{0} \rightarrow \pi^{+}\pi^{-}\pi^{0}$	SLAC H. Saal U. C. SANTA CRUZ D. Dorfan UNIV. COLORADO U. Nauenberg	8/6/69*	С
E-60	Hyperon Production in K [¬] P Interactions	SLAC K. Bunnell, R. Mozley, A. Odian J. Park, B. Swanson, F. Villa, L. Wan <u>UC-RIVERSIDE</u> S. Fung, A. Kernan, R. Poe, T. Schalk, B. Shen <u>LRL-BERKELEY</u> M. Alston-Garnjost, R. Bangerter, A. Barbaro-Galtieri, F. Lynch, F. Solmitz	g g	d
BC-5	A Proposal to Study Many Particle Final States produced by 12 GeV/c π^- Mesons at SLAC	UNIVERSITY OF HAWAII A.Kohya, <u>M.W.Peters</u> , V.Peterson, V.Stenger, A.Johnson, N.Rogers, P.Wohlmut	12/16/67	С
BC-6	Proposal to SLAC for Study of the One Pion Exchange Contribution to γ -Nucleon Scat- tering (in 40-Inch Deuterium Bubble Chamber)	OAK RIDGE H.O.Chon, R.D.McCulloch UNIV. OF TENNESSEE G.T.Condo, W.M.Bugg	9/28/68	с
BC-10	A Proposal to Investigate K_2^{Op} Interactions with the 40-Inch HBC	STANFORD B.C.Shen, D.W.G.S.Leith, A.D.Brody, W.B.Johnson, R.R.Larsen, G.A.Loew, R.Miller, W.M.Smart	5/11/68	d

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Table of Programmed Experiments (cont'd) - 4

-	Number	Title	Authors	Date Approved	Status
- 20 -	BC-11	A Bubble Chamber Experiment with the Polarized Laser Induced Photon Beam (Extended 10/3/69)	SLAC J. Ballam, G. Chadwick, Z. Guiragossián, P. Klein, A. Levy, M. Menke, J. Murray, G. Wolf <u>TUFTS UNIV.</u> C. Sinclair <u>UC-BERKELEY</u> H. Bingham, B. Equer, K. Moffeit <u>UCLRL</u> M. Rabin, W. Podolsky, A. Rosenfeld	5/11/68	c,i
	BC-13	Proposal for a 3,000,000 Picture 7.5 GeV/c π p Exposure in the 82" Bubble Chamber	UNIV. OF ILLINOIS G.Abrams, G.Ascoli, B.Crawley, B.Eisenstein, R.Hanft, U.Kruse, D.Mortara, T.O'Halloran, R.Sard	8/5/68 Ext. 12/12/69	d
	BC-14	Proposal for 7.5 and 13 GeV/c, π^+ and π^- Exposures in the SLAC 82" HBC	MIT P.L. Bastien, D. Brick, T.Dao, B.T. Feld, R.I. Hulsizer, L.Kirkpatrick, V.Kistiakowsky, H.Lubatti, D. Miller, A. Nakkasyan, G.Ouannes, I. Pless, A.Sheng, T.Wa F.Winkelmann, J.Wolfson, R.Yaman	8/5/68 tts noto	с
	BC-18	A Proposal for a 4.25 GeV γ -Deuterium Experiment in the SLAC 40" Bubble Chamber	WEIZMANN INSTITUTE Y.Eisenberg B.Haber, U.Karshon, L.Lyons, E.E.Ronat, A.Shapira, G.Yekutieli	9/28/68	С
	BC-19	A Proposal for a γ -d Experiment with an Annihilation Beam of 7.5 GeV in the SLAC 40" Bubble Chamber	TEL AVIV UNIV. G.Alexander, I.Bar-Nir, A.Brandstetter, S.Dagan, J.Gunhaus, A.Levy, Y.Oren	9/28/68	a, h
	BC-25	Proposal to Study Pomeranchon, Meson and Baryon Exchanges by Triggering the SLAC 40" Bubble Chamber on Fast Forward Particles	CAL TECH B. Barish, W. Ford, R.Gomez, C. Peck, J. Pine, F. Sciull B. Sherwood, A. Tollestrup, G. Zweig	6/18/69 i,	d
	BC-26	Determination of Quantum Numbers for Resonances in the R, S, T, and U Region Using π^{+} + d Interactions at 12 BeV	DUKE UNIV. M. Binkley, D. Carpenter, L. Fortney, C. Rose, E. Fowler, J. Elliot, J. Golson, V. Joshi, J. Kronenfeld, T. Snow, W. Yeager	6/11/69	d

Table of Programmed Experiments (cont'd) - 5

Number	Title	Authors	Date Approved	Status
BC-27	Study of the "A ₂ " Problem and Other Members of the $J^P = 2^+$ Nonet	BROOKHAVEN NAT. LAB. D. Crennell, U. Karshon, K. Lai, R. Kinsey, J. O'Neall, W. Sims, J. Scarr	6/11/69	d
BC-28	Proposal for a 5 GeV/c π^+ p Experiment in the SLAC 82 Inch HBC	WEIZMANN INSTITUTE OF SCIENCE Y.Eisenberg, B.Haber, U.Karshon, E.Ronat, A.Shapira, G.Yekutieli	8/6/69	d
BC-30	Ap Interactions in the Momentum Interval 1-5 GeV/c	LRL-BERKELEY G. Trilling, J. Kadyl G. Goldhaber, J. Hauptman	K, 12/12/69	d
BC-33	300,000 Pictures, 4.5 GeV/c π^- in H ₂ 82-Inch Bubble Chamber	UNIV. OF PENNSYLVANIA S. Barish, J. Bensinger, E. Bogart, P. Jacques, W. Selove	12/12/69	đ
NT-3	Fast Cycling Bubble Chamber Development	SLAC H. Barney, R. Blumberg, A. Rogers, S. St. Lorant	12/15/68	g
D-6	Charpak Wire Chamber Tests	SLAC E. Bloom, K. Doty, G. Johnson, R. Siemann	9/15/69	i
D-9	Magnetic Bremsstrahlung	ILLINOIS INSTITUTE OF TECH. T. Erber, F. Herlach, H. G. Latel	2/8/69	d

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a. Experiment is in data collection phase and was a prime user of accelerator time during the period.

b. Experiment is in checkout phase and used accelerator time for checkout purposes.

c. Experiment was being set up in the research yard during the period.

d. Experiment was inactive in the research yard during the period.

- e. Beam is under construction.
- f. Experiment ready for future scheduled run.
- g. Used parasite beam time during the period.

h. Experiment completed.

- i. Special test run performed.
- * Approved for checkout only.

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III. ACCELERATOR IMPROVEMENTS

Blind tuning of the accelerator was completed in November and beam breakup tests indicated that the beam breakup threshold has been raised to 77.5 mA. Sectors 3, 4, 5, 10, 13, 16, 22, 25 and 28 have been blind tuned by 2 MHz and sectors 12, 15, 18, 21, 24, 27 and 30 by 4 MHz.

Installation of pulsed steering and focusing equipment in four sectors of the machine continued during the quarter. Installation of the second quadrupole doublet was completed in November and of the third doublet in December. Fabrication of the second quadrupole power supply, which had been delayed by receipt of a transformer from strike-bound General Electric Co., was completed in December, but installation was delayed until January. The third pulsed steering power supply was installed in November.

Installation of the first phase of the off-axis injector was completed in November. Test results were satisfactory, but it was discovered that the high field main injector solenoid tended to divert the off-axis beam. A method of shielding the off-axis injector from this solenoid is being studied and tests will be run in January.

The second phase of the off-axis injector, using a pulsed alpha magnet still to be built and a new gun modulator nearing completion, will be completed later in the fiscal year. The second phase will permit simultaneous use of the two injectors on a pulse-to-pulse basis.

Engineering effort was begun on pulsed beam loading compensation. A prototype of a delay control circuit is being built and will be installed in one of the sector trigger generators for testing.

A prototype test target for the positron source was fabricated during the quarter and installed at the conclusion of the December experimental run. This target will use the "twitching" principle to deliver interlaced positrons and electrons by means of diverting part of the beam, on a pulse-to-pulse basis, around the target to deliver electrons and by allowing the balance of the beam to hit the target to deliver positrons. The principle has been successfully tested with a stationary "wheel" target, but runs were restricted to low power due to the "wheel" construction. Construction of the new target, utilizing tungsten-copper layers, will provide greater power absorption.

IV. RESEARCH DIVISION DEVELOPMENT

A. Physical Electronics

Glass Semiconductors

A Normarski interferometer was adapted for use as a film-thickness measurement station for rapid nondestructive evaluation of evaporated thin films. Filmresistance measurements as a function of temperature and frequency are continuing; equipment is being modified to reach lower temperatures and provide more stability. As a service to the Spectrometer Group, the Beckman spectrophotometer was used to measure the ultraviolet transmission of Rohm and Haas plexiglass and of various cements.

Several devices were fabricated for film resistance and capacitance measurements, but were found to be contaminated with diffusion pump oil. The problem was traced to a defective valve which is now being repaired.

The Beckman DK-2 spectrophotometer is being realigned for more accurate measurement of plexiglass and cement transmission characteristics. Secondary-Emission Particle Detector

A new brazing technique has been developed for attaching vacuum-tight windows to a stainless steel flange. A silver ring, onto which a window is held by silver chloride, is heated while in place on an electrolytically coated stainless steel vacuum flange. Some portion of the silver combines with the coating to form a eutectic liquid, which flows into a vacuum-tight seal. This technique can possibly be extended to the brazing of an insulating substrate or window directly to a metal part.

A high yield secondary emitter comprising GaAs-CsI-Cs was tried with limited success. Apparently a potential barrier at the GaAs-CsI junction of 0.5 eV caused a drastic decrease in the efficiency of the surface treatment. To remove this barrier, an intermediate layer of Cs will be added to form a structure of GaAs-Cs-CsI-Cs. A trial of this surface treatment is being made on a silver sample.

There has been some interest recently in the change of scintillation luminescence caused by a high electric field in the detector. Mechanisms which have been postulated include field ionization of excitons or a field enhanced hole mobility in a scintillating alkali halide detector crystal. No evidence for hole mobility at low fields is to be found in the literature. We are investigating the possibility of fieldenhanced hole mobility in CsI by transit-time measurements on crystals stressed to nearly the breakdown electric field. A vacuum dewar has been modified for the measurements, and a pulse light source for creating holes has been constructed.

B. Magnet Research

SLAC 12" Coil Modification

The middle module of the coil is unstable. It was difficult to energize the coil to a current level of 400-500 A with the rest of the magnet without subjecting the magnet to a quench. As a field of 70 kG is required for many experiments, we decided to rewind this module.

Approximately 16,000 feet of a new stabilized composite conductor was acquired. The conductor has one section of 178, and another of 121 filaments, both with a cross section of 0.06×0.06 in. The conductor was delivered in 8 lengths, due to some accident in the manufacturing process, and we have been forced to join the conductor by the method described below. By the classical method of overlapping approximately 6 feet of two conductors, wrapping them with a superconductor, and indium-impregnating them, we produced a joint which has a resistance of less than 10^{-10} ohms. One joint was cut out from the magnet, wound into a small coil, and tested up to 60 kG, in order to make sure that we will not run into any difficulties when the 12" coil is operated.

One coil module, with 9000 feet of conductor, is insulated and wound. The second module will follow.

A dewar insert is being built which enables us to perform tests either at very low temperatures — say less than 1.8° — or higher temperatures, up to liquid nitrogen temperature, if necessary. Counting all modifications which are planned, we expect to produce a field in excess of 70 kG at the magnet center at a maximum helium boil-off rate of 8 liters per hour, with a charging time of ~1 hour, which would enable us to operate the magnet from a small A. D. Little refrigerator acquired from the Physical Electronics group.

Short Sample Tests

Fifteen hundred feet of the bubble chamber magnet conductor $(.375 \times .25 \text{ in.}, 600 \text{ filaments})$ was delivered by Airco, and a set of measurements was performed up to fields of 65 kG on the conductor. The first measurements indicate that al-though the conductor is absolutely stable up to 4500 A at 65 kG, it has a slight ohmic component of 5×10^{-9} ohms over 6 mm length of conductor at 65 kG transverse field, which indicates that a few filaments may either be broken, or they are cold-worked and, therefore, only partially superconductive. Discussion with the company indicates that we should measure more samples by eliminating about 25-50 feet from the conductor is satisfactory or modifications of the conductor should be undertaken.

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The samples received from Supertechnology have been tested in the standard way and in a 2-layer solenoid; fields of up to 62 kG and a current density of 15,000 A/cm^2 were achieved. These values are acceptable for some intended uses, but not for others. In close collaboration between SLAC and Supertechnology, the successive annealing processes are being modified, with the goal of reaching fields of 75 kG at a stable current density of 25,000 A/cm^2 .

1/10th Scale Model of the Wire Spark Chamber Spectrometer

The modified shimmed wire chamber magnet model is being assembled. A new series of tests on the field distribution and field homogeneities will be starting the latter part of January.

Bubble Chamber Modification

In order to test the performance of the conductor, which should, in final design, carry 2500 A at 83 kG, a series of 3 double pancakes will be wound and placed within the two halves of the SLAC 12" coil. These double pancakes have an inner diameter of 12" and an outer diameter of 38". The combined 12" coil and 3 double pancakes will deliver a total central field of 80 kG, corresponding to a maximum field in the conductor of 85 kG. The engineering drawings for these double pancakes have been completed. The winding will start as soon as the second intermediate module of the SLAC 12" coil is wound.

For further tests of the conductor, a room temperature insert dewar is completed. Also finished is a test fixture to strain the conductor in liquid helium at different fields.

Superconducting Joint Measurements

Superconducting joints made by the explosion method have not been satisfactory. Several new types of joints proposed by Shock Hydrodynamics are currently being studied.

However, for small composite conductors, with dimensions of 1×1 mm or so, SLAC's Physical Electronics Group has been producing joints by the method of spotwelding the superconductors and successive annealing. Although this work is in a very preliminary stage, the results so far have been quite promising. If the joint is at a low field area, the samples carry more than 80% of the current of the virgin short sample. Such joints are usable if we locate them in field-free regions, which is quite feasible. Improvements of the joints are in progress.

Thermal Conductivity

In the first phase of measuring thermal conductivity, it was reported that measurements of annealed NbSn had begun. In a series of new experiments, we

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measured, at 1.5° K, a thermal conductivity value of about $650 \text{ mW}/^{\circ}$ K cm. Due to the limitations in the capacity of our vacuum system, it was at first not possible to reduce the temperature further.

However, we finally succeeded in producing 1.1° K in the helium bath, which enabled us to measure thermal conductivity down to 1.2° K. Compared to values of nonannealed Nb, which were reported earlier, the thermal conductivity of annealed high-purity Nb fluctuates around 900 mW/ $^{\circ}$ K cm at 1.5° K and drops very fast to about 400 mW/ $^{\circ}$ K cm at 1.2° .

With this scheme, the first phase of the work has been completed. Measurements of nonsuperconducting Nb at higher temperature, about 10^{0} K, will be conducted soon.

C. Conventional Data Analysis

Maintenance

Measuring Machine M4 installation has been delayed due to electronic design changes. Final checkout should be completed during the 1st week in January.

Fabrication of the SP-6 Scanning Machine mechanical parts is being delayed intentionally to match the schedule for electronics parts.

An interlocking limit switch and cam mount was fabricated and installed on the Spiral Reader Measuring Engine. This permits the operator to transport film manually only when the film platen is in line with the supply and takeup reels.

Three rotary position encoders on the Vanguard measuring machines failed. As a result one of these machines will be out of service until at least March 1, 1970 while the defective units are repaired at the factory.

We will begin interfacing the new NRI table to the computer in the near future. Programming

<u>NRI System</u>: A Tape Operating System containing BUCAPS has been assembled and is being checked out. This system should make it easier to recover from "crashes" due to hardware or software failures.

Some preliminary work has started on the changes needed in the NRI system BUCAPS program to accommodate two new experiments: E-48 (Measuring the ξ Parameter in the Decay $K_{L}^{0} \rightarrow \pi \mu \nu$) in the Streamer Chamber and E-40 (Production of Charged ρ^{\pm} Mesons, Neutral ρ^{0} Mesons, f⁰ Mesons and Nucleon Isobars by Pions) in the Spark Chamber. Development of an EMR 6020 Assembler has been started. This project will be followed by software which will prepare and edit master tapes for the 6020. Both of these packages will execute on the IBM 360/91. This means that system preparation will usually be done without preempting measuring, and system time on the 6020 should be limited to checkout.

In <u>October</u>, 51,000 events were measured in 3500 hours and 492,000 frames were scanned in 3100 hours. The EMR-6020 computer serving the NRI measuring tables was down 24% of the time this month. Despite this large amount of downtime, over 18,000 events were measured on the five NRI tables now available for measuring. The Hummingbird measuring exceeded 9000 events and the Spiral Reader has reached the production stage: 7000 events were measured in October.

In <u>November</u>, 27,000 frames were scanned in 2400 man-hours. On several experiments, special scans are now being done; this results in fewer total frames per month. 41,000 events were measured in 3100 man-hours. Of these events measured, 16,500 were done on the NRI system, 8000 on the Spiral Reader, 3000 on the Hummingbird, and the remainder on manual measuring machines.

Fewer events were measured in <u>December</u> due to the holidays, reduced usage of the automatic machines, and the large amount of downtime of the EMR (NRI) computer. This computer, which controls five measuring tables at the present time, was down 36% of the time during the first three weeks of December; the measuring tables are inoperable whenever the computer malfunctions. A total of 32,000 events were measured during December in 2500 man-hours, and 400,000 frames were scanned in 3200 man-hours. The NRI system of measuring tables produced 14,500 of the events that were measured. The two automatic measuring machines produced slightly over 10,000 events; there were 7800 events measured on the Spiral Reader in 210 hours and 2600 events on the Hummingbird in 65 hours. The remainder of the events were measured on the Vanguards and SPVB's which are conventional measuring machines.

Work began in the scanning department on a new experiment. This is a Group D experiment and uses a beam of K^0 particles in a streamer chamber. Unlike previous streamer chamber film, the vertices of the particle interactions are visible in this new film. It is anticipated that this and other improvements in the quality of the film will permit more rapid scanning and measuring of this film than was possible with the old style streamer chamber film which was quite difficult to scan and to measure.

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D. <u>Computation Group Activities</u>

Accelerator Control

Work is continuing on the new operating system for the PDP-9 in the accelerator control room. The specifications for this system include: a disk monitor which will roll in programs as needed into dynamically chosen areas of core memory; a timed sequence scheduler which will force delays at user-assigned points in the programs to allow relays to close, analog signals to become available, etc; a storage management scheme which permits a degree of reentrance of subroutines. The interim operating system has been operational for some time now and computercontrolled on-line replacement of klystrons continues to operate. The quadrupole setting program is also operational, but it will not yield any gain in accelerator performance until the hardware interface is modified for simultaneous control of 30 sectors.

Since the recent DAB/CCR control room reorganization decision, some concrete plans on how to integrate the two control room computers are being made. The plans envision the DAB system to be mostly involved with the man/computer interface (command interpreter, scopes, push button handlers) and the CCR system to concentrate on the accelerator/computer interface. Between the two will be a data link requiring only moderate data rates, over which will pass high level commands such as "SET BEAM LINE 1 TO 10 GeV." In the other direction, compressed accelerator data for scope display, refreshed every 2 seconds, will go to the DAB. Graphics

GEMS, a graphical experimental meta-system, is now completed. It provides facilities for defining and implementing linear string graphical languages; it allows these to be debugged interactively and then run as slave programs (i.e., normal plotting usage) with no required programming changes. It is constructed in a manner which permits device independence. Although primarily aimed at generation languages, it does provide some help with recognition languages. The aim of GEMS is to allow an economical experimentation with formalized graphical languages such as Allan Shaw's Picture Description Language.

SIMPLE, a simple precedence translator writing system, is also completed and was used in implementing GEMS. It is written in PL/1 and generates PL/1source code for an application. SIMPLE allows one to experiment with new languages (such as small compilers) and provides a parser for the language which includes automatic error recovery and error diagnostics related to the defined language.

Access Control and File Security

The soundness of the formulary model of access control internal publication (CGTM 60, February 1969) was checked out.

Blocking mechanisms which allow only one user read or write access to individual data items were redesigned from the initial ones of CGTM 60, and then were tested. They are now checked out.

Experiments on interactive methods of access control were carried out in cooperation with the Stanford Computation Center, using a new interactive subsystem (WYMPI) which is not yet available for general use. Some initial efforts to ascertain overhead costs of certain access control procedures were also made, and further experiments are being carried out in this area.

SPASM Fast Assembler

The initial successes of the SPASM Fast Assembler have led to a number of extensions and improvements in the system. Because the major uses are expected to remain in the area of short programs and debugging styles of runs, most of the effort has been directed toward providing additional diagnostic and language capabilities, rather than improvements to performance, which is already significantly greater than that available from any comparable processor.

Two additions to the diagnostic and tabular facilities were made: these are the USING map, and Type Checking. Because one of the major areas of difficulty for the Assembler-Language programmer is with the specification of the USING statement, SPASM now provides a post-assembly map of the range and values specified by each of the USING statements in his program. This enables him to determine immediately whether his assumptions regarding the span of a set of statements are correct, and helps to eliminate simple but difficult-to-find errors at an early stage of the programming process. The Type Checking facility is also directed at the elimination of simple or careless errors: it often occurs that data will be stored or accessed by the programmer at a place where some other type of data is expected. While the use of Assembler Language usually implies that such treatment of the data is allowed, there are many situations where the mixture of data types implied by the declared storage area and the instruction that will use it is not intended. SPASM will now diagnose many such inconsistencies, and emit a low-level diagnostic; it is intended more as a reminder to the programmer that there may be hidden problems in his program. This facility can be thought of as providing some of the features available in higher-level languages, where declaration statements associate various
properties with variables; this extra information is then used to determine whether later uses of the variables in imperative statements is correct, and to control the type of code generated. Unfortunately, past Assembler Languages have made essentially no use of such semantic information.

Language extensions have been mainly in the direction of a macro-instruction capability. As an initial step in that direction, a number of changes were made to the routines which direct the internal flow of data among the processing routines of SPASM; having made those changes, it was easy to add a number of other useful facilities. Among these are (1) the ability to "defer" the assembly of text, and (2) the ability to redefine, undefine, and replace the operation codes accepted by the system. The DEFER facility allows the programmer to specify that groups of statements are to be collected under an internal filename either in stacking or queueing operations, and then to reinsert them in the source statement stream at a later time by specifying the filename. Uses for such a capability might be (for example) the definition of a group of constants, and the generation of code to provide closures of loop-control statements, where the proper nesting of the groups is handled automatically by the deferring mechanism. The redefinition facility allows the programmer complete control over the meanings of all the operation codes to be used in his program. For example, he can define a simple subset of the Assembler Language to be used for a restricted set of data types, and be assured of greater consistency of usage, better reproducibility on other machines, and greater ease of learning for the novice programmer. It also allows certain operation codes to be replaced by macro-instruction definitions, which can be written in such a way that the instruction can be checked for validity at assembly time, and diagnostic information can be generated that is more helpful than anything that could be given at execution time.

Current efforts are directed towards the addition of the macro-capability, and the provision of literals. Future efforts might include expanded cross-references tables, multiple control sections, relocatable object code, external macro-libraries, accounting data and error summaries for later analysis, some sorts of terminaloriented operation, free-running execution, and a number of internal reorganizations.

V. PLANT ENGINEERING

During the quarter several projects were completed and the facilities placed in use. Included were: additions to the LCW pumping and heat exchanger capability in the research yard; enclosing of the klystron pulse tank maintenance area in the Test Laboratory; installation of improved drive line insulation throughout the thirty sectors of the Klystron Gallery; and enclosing of room 109B in the Cryogenics Laboratory. In addition, several construction projects were virtually completed and will be finalized in January, 1970. These were: upgrading of building 101 for use as a developmental vacuum laboratory; enclosing of the Fabrication Building cleaning shop; construction of a 1000 gross sq ft extension of the Data Assembly Building; and establishment of a machine shop clean room in building 107.

Field work is in progress on various other projects, as follows:

1. Relocation of the SLAC Library — construction of the new facility in the Central Laboratory is 80% complete and the work is progressing well.

2. End Station "A" North Wall — concrete blocks are being procured for an 800 gross sq ft triangular extension of the shielding wall for extended use of the spectrometer facilities.

3. Front Entryway Improvements — the foundation slab for a new information booth has been poured and the balance of the work should be finished in the next quarter. Most of the landscaping at the new entryway is in place.

4. Modifications of Radioactive Water Service — this installation in the end station "B" target room is well along and will be completed during the next several months as scheduled outages of the accelerator permit.

Preliminary work on a number of items, as stated below, is underway:

1. Central Utility Building Expansion — design for the addition of two 50-ton chillers and a ten-foot extension of the building to house them has been started.

2. Upgrading of Buildings 102 and 104 — design for the incorporation of office, rest room, and work shop space in these target area buildings is complete. Construction bids will be invited in the near future.

3. SLAC 230 kV Tap Line — consideration is being given to the dead-ending of pole structure #35 as a preventive maintenance measure.

4. Superconducting Accelerator — an engineering study for the conversion of the SLAC two-mile machine is being continued.

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Effective January 1, 1970, the allocation of electrical power from the Bureau of Reclamation is to be increased from 40 to 45 megawatts. This is based on an analysis of SLAC power costs and the predicted electrical load for the next several months.

The ongoing program of plant utility operation and minor modifications to buildings and grounds was continued throughout the quarter. The extension of electrical and mechanical services for new beam line facilities and the adaptation of target area buildings were continuing requirements.

VI. KLYSTRON STUDIES

A. Development

1. High Power Klystrons

<u>Litton Subcontract</u>. The rate of delivery and acceptance of Litton tubes continued to be extremely satisfactory during the quarter, with a total of 23 tubes accepted during the quarter.

<u>RCA Subcontract</u>. The evaluation of RCA tubes designed for operation at 270 kV, 30 MW, has continued with the acceptance of 2 end-of-life 30 MW tubes and 1 full specification 30 MW tube. The total number of acceptable RCA tubes was 7.

<u>SLAC</u>. The work is continuing on further improvements of the SLAC tube efficiency. During the quarter we continued tests of XM-16A klystrons. These tubes are similar to tubes built experimentally in 1968. The high voltage seal failures and other problems had prevented the operation of the 1968 versions in the gallery although the experimental results indicated the validity of the design changes made to improve performance.

Table II gives the performance of the 8 XM-16A's built and tested during 1969. The results of both electromagnet and permanent magnet tests for the 5 accepted tubes are given in Figs. 3 and 4.

In addition, some theoretical analysis indicated that the drift distances are not yet optimized in the XM-16A. XM-16B's and C's are planned with modification of these drift distances. Two (2) XM-16B's were built. One has been tested and gave an efficiency slightly in excess of 50% at 250 kV in electromagnet; its performance in both electromagnet and permanent magnet is shown in Fig. 5.

2. Klystron for Superconducting Accelerator

The first tube design has been completed and all the parts have been machined by the end of the quarter. Additional design work is being conducted with the idea of improving the efficiency by using a smaller drift tube diameter.

Test diodes have been built for evaluation of oxide cathode and dispenser cathode probable life. Diodes having each type of cathode are at present in life test.

3. High Power Windows

Probably because of the higher operating level of SLAC tubes, the window operating temperature is higher on the average than we had experienced during previous years. Window edge temperatures of 130° C are fairly common at

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TABLE II

XM-16A TUBES BUILT AND TESTED IN 1969

TUBE	DATE OFF BAKE	DISPOSITION AND COMMENTS
K-223	8/1/69	Accepted, 34.8 MW at 270 kV, drive
		~ 100 watts
K-224	8/8/69	Gassy during initial tests, collector
		damage-waiting rework
K-225	7/8/69	Accepted, 33.5 MW at 270 kV, drive
		~ 500 watts
K-228	10/21/69	Accepted, 32.9 MW at 270 kV, drive
		~ 450 watts
K-229	11/10/69	Accepted, 33.8 MW at 270 kV, drive
		~ 250 watts
K-230	11/18/69	Gassy when removed from bake, failed
		initial tests (gassy) — in rework
K-231	11/24/69	Leak in window when removed from bake
		in rework
K-234	12/15/69	Accepted, 31.2 MW at 270 kV, drive
		~ 75 watts





FIG. 4--Electromagnet tests (at optimum focus) of accepted XM-16A tubes.



FIG. 5--Performance of XM-16B tube.

operating levels with 35 MW peak, 30 kW average. However, the center edge temperature gradients do not appear to exceed 30° C so that the risk of thermal failure is probably not too great. However, the maximum coating thickness has been slightly reduced (to 70 Å) in an attempt to reduce the operating temperature. For the same reason we will probably water cool the waveguide and the window flanges, and try to increase the radiation from the window in order to further reduce the overall window temperature.

4. Driver Amplifier Klystrons

No major problems were encountered during the quarter. However, since the reduction in operating voltage of the tubes in the gallery we may wish to redesign the tube to increase the gain at the lower operating voltage.

5. Special Problems

<u>RF Loads</u>. Probably because of the increase in peak and average power level of both SLAC and RCA tubes during the last quarter, we have begun experiencing a large number of water load failures in the test laboratory. Cold tests indicate that in the present load the power absorption is not uniform as a function of length, and that most of the power is absorbed in less than 5" of water column. Two new load designs are being cold tested with the hope that the power absorption will be reasonably uniform over a water column length of at least 15".

<u>Computer Program</u>. We obtained during the quarter information on the LASL "Confined Flow Klystron Code Operation" and have been able to adapt it for use in the SLAC Model 360 IBM computer.

We are planning on developing a code at SLAC but since the model is completely different and has not been proven, we plan to use the LASL code to gather experience and if necessary expand it to be more comprehensive. The present code is only one dimensional and is restrictive in its usage for klystrons using a Brillouin focusing scheme or where radial and azimuthal forces significantly influence the beam wave equations in large signal klystron theory. We plan to thoroughly test this code on all our models and relate the results back to LASL. We are especially interested in the results in the relativistic domain since a large discrepancy was observed on previous runs made at Los Alamos.

6. Vacuum

Experiments have begun on the effect of vacuum on the stability of the Viton O-rings used in the valves in the accelerator. These experiments were instigated as a result of some questions relating to the probable life of the valve seats in the

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accelerator valves. Up to now a few samples have been removed from the vacuum after being under vacuum for approximately 3 weeks. A definite weight loss was observed in all samples; and the hardness of the samples has increased as a result of the exposure. However, after 3 days of exposure to air a portion of the weight was regained and a reversal was observed in the hardness change. To our knowledge these phenomenon had never been reported in literature. However, the main goal of this experiment is long term stability of the O-ring materials.

<u>Pump Stability Studies</u>. We are attempting to compare the stability of inert gas pumping by conventional titanium ion pump and tantalum-titanium ("differential") ion pump. The preliminary results indicate there are probably at least 2 types of instabilities for the conventional ion pump. In one case the pumping speed appears to have periodic variations resulting in almost sinusoidal pressure excursions from 2×10^{-5} to 4×10^{-6} torr. The more familiar form of pump instability is a more sudden jump which may result in a pressure change of 2 orders of magnitude lasting for approximately one-half minute until the pump recuperates.

The differential pumping ion pump indicates a basic pumping speed for argon approximately 4 times that of the conventional ion pump. However, this pump also showed signs of instability after prolonged pumping of argon at a pressure of approximately 2×10^{-6} torr. The instabilities are so unpredictable that no systematic observations of the behavior of the pump has been possible to date.

B. Operation and Maintenance

With somewhat more than 300,000 klystron hours of operation we experienced only 10 failures during the quarter. As a result the number of spares continued to be eminently satisfactory.

We gradually increased the number of sockets operating at 30 MW so that by the end of the quarter there were 12 klystrons operating at 265 kV.

There were 3 driver amplifier failures.

1. High Power Klystron Operation

Table III gives the summary of usage and failures of all klystron vendors (except Sperry) since the beginning of operation.

The data given in the table is also shown graphically in Fig. 6 in which in addition the cumulative hours per socket and mean age of all operating tubes are given.

TABLE III

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KLYSTRON MTBF

	PER QUARTER			CUMULATIVE				
Dates	Operating Hours	Fai Number	lures Mean Age	MTBF	Operating Hours	Fai Number	lures Mean Age	MTBF
To 6/30/66					129,400	19	260	7,200
To 9/30/66	111,000	8	610	14,000	240,400	27	360	9,000
то 12/31/66	154,000	11	1,100	14,000	394,400	38	575	10,300
То 3/31/67	207,000	13	1,490	15,900	601,400	51	810	11,800
то 6/30/67	287,000	9	2,490	32,000	888,400	60	1,060	14,800
то 9/30/67	330,500	25	2,860	13,300	1,218,900	85	1,590	14,500
To 12/31/67	263,000	21	3,520	12,500	1,481,900	106	1,980	14,100
To 3/31/68	309,500	17	4,800	18,200	1,791,400	123	2,360	14,700
To 6/30/68	306,000	15	3,820	20,400	2,097,400	138 .	2,520	15,200
То 9/30/68	314,200	24	5,500	13,100	2,411,600	162	2,960	14,900
To 12/31/68	349,800	23	8,350	15,200	2,761,400	185	3,630	15,000
To 3/31/69	328,600	20	6,610	16,400	3,090,000	205	3,930	15,100
то 6/30/69	335,000	16	7,280	19,700	3,425,000	221	4,190	15,400
To 9/30/69	179,800	8	11,670	22,500	3,608,100	229	4,450	15,750
To 12/31/69	303,600	10	10,230	30,400	3,911,700	239	4,690	16,300



FIG. 6--High power tubes: cumulative MTBF, mean age at failure, mean age of operating tubes, and cumulative hours per socket, January 1, 1970.

The tube age distribution of all operating tubes is given in Fig. 7. Over 35% of the tubes in use have operated for more than 15,000 hours. The mean age of all living tubes is 10,600 hours and median age is 12,200 hours. Figure 8 gives the age distribution of all failures through December 31, 1969. Their mean age is 4,690 hours with a median of 3,750.

From the data shown in Figs. 7 and 8 the failure probability and survival probability average for all tubes has been computed and is shown in Fig. 9. The causes of failures are distributed approximately as follows:

Windows	40%
Power output breakup	3%
High voltage seal puncture	6%
Tube vacuum	20%
Cathode arcing	23%
Loss of emission	4%
Miscellaneous	4%

The effect of operating level on the probable klystron life has always been of great concern to us. This is particularly true since we started operation at 265 kV. An attempt to analyze the failure rate of tubes operating at 265 kV gives the results shown in Fig. 10. There have been 3 tube failures as indicated; in addition 3 other tubes had to be removed from 265 kV operation because of excessive faulting, but are still perfectly usable as 250 kV tubes. There are 13 operable tubes at the present time. Using the 3 completely failed tubes one can compute a survival probability which is given by the solid line in Fig. 10. By counting in addition the 3 tubes which are no longer usable at 265 kV as failures one gets the dotted line in the survival probability graph of Fig. 10.

It is obviously too early to make any predictions as to the real probable life for this level of operation. However, comparison of Figs. 9 and 10 indicates that the probable degradation of life should be minimal.

After more than 15,000 hours average operation per socket it appeared interesting that we consider the number of replacements among the various stations. The result is given in Fig. 11 which gives the number of stations in which zero, 1, 2, 3, etc., replacements have taken place since the beginning of operation (replacement of Sperry tubes has been discounted since they do not appear in any of our statistics at present). It is interesting to note that 18 stations have not had a tube replacement since the beginning of operation; also the curve appears to

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FIG. 8--High power tubes: age-at-failure distribution, January 1, 1970.



FIG. 9--High power tubes: survival and failure probability, January 1, 1970.







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FIG. 11--High power tubes: replacement distribution through January 1, 1970.

follow a perfectly normal statistical distribution. Hence there is no indication that any stations are giving unexpectedly large number of replacement problems.

After more than 3 years of continuing operation it also appeared desirable to run some checks into the possibility of a change in tube power output as a function of tube operating life. In many cases tubes are retested after many hours of operation and found to be perfectly operable. The power output data of 90 retests of tubes which had been in the gallery for at least 5,000 hours since the original acceptance test and still met specifications was compared with the initial acceptance test power output. The average age at retest was slightly over 10,500 hours. The average change in measured power output was 0.2% although individual tubes varied as much as $\pm 10\%$. In view of the above there appears to be no evidence of deterioration of tube operation up to approximately 15,000 hours.

2. High Power Klystron Maintenance

An increase in the amount of beam time delivered by the accelerator at energies of 18 GeV or greater made the demands on klystron reliability and performance more stringent. Despite this the rate of trouble reports dropped to less than 1 per 1,000 hours of operation; the rate of replacement stayed substantially constant at 0.1 per 1,000 hours of operation.

The indications are that the operation at 245 kV has not degraded the reliability of the klystrons up to now. Similarly the tube replacement rate and trouble reports in the stations operating at 265 kV are near the mean of trouble reports and replacement rates for all sectors for the month of December.

Figure 12 shows the operating experience since the beginning of operation.

3. Driver Amplifier Klystrons

The number of failures and replacements on driver amplifiers continued to be minimal (close to 15,000 hours MTBF).

A new modulator has been completed for the rf separator station and a driver amplifier klystron will be installed prior to the first operating cycle of 1970.

The tube age distribution of all driver amplifier tubes as given in Fig. 13 is an indication of the satisfactory performance of these tubes. Figure 14 gives the age distribution of all failed driver amplifier tubes.

4. Main Booster Klystrons

No difficulties were experienced with the main booster klystrons during the quarter.













5. Vacuum System

No major problems were encountered during the quarter. Pressure at the main manifold gauges averages 1.5×10^{-8} torr when klystrons were operating. Ion pump argon instability was a problem at station 1-6 so an Ultek D-1 type pump was installed at station 1-8 and the gas bursts ceased. In addition differential ion pumps were also installed at the injector.

VII. INSTRUMENTATION AND CONTROL GROUP (July - December 1969)

A. Beam Guidance System

Pulsed Steering and Quadrupoles

A number of pulsed steering and focusing supplies have been installed in the accelerator. Pulsed beam-loading controls and additional pulsed steering and quadrupoles will be installed during the coming year. To date, each pulsed device has been provided with two levels switched by the beam patterns. Each level has its own controls and meter. The pulsed device is capable of expansion to provide for six pulsed levels, one for each beam. Two modifications of the control system will be installed to reduce the quantity of additional wiring and the complexity of the control panel. The change is to monitor the pulsed device on a pulse-by-pulse basis just as our beam monitoring signals are now monitored. A selector switch at the beam guidance display scopes will select display of log Q, pulsed quad, pulsed horizontal steering, pulsed vertical steering, or pulsed beam-loading delay. The selected pulsed device will be monitored in all sectors and transmitted to Central Control Room (CCR) by the present log Q channel. The analog signals will be monitored using a sample-and-hold technique to record the steering or focusing currents at the instant of the beam pulse. The log Q scope presently displays a row of spots whose displacement represents the logarithm of beam current at each drift section. The alternate displays will show the value of the selected signal for those sectors where the corresponding device is installed. Initially, the spots representing the other sectors will continue to display log Q. Eventually, the other sectors will remain on the base line. The multiplexing switch, which replaces the log Q signal by the selected monitor signal, has been installed in sector 28, and appears to work correctly. The switches will be added in other sectors during the next six months. As soon as six-level monitoring is installed, the six beam patterns will be transmitted to each pulsed device so that one level will correspond to each beam. The installation of pulsed quads and steering will give the operator a lot more controls to handle. The installation of the computer has opened the way to establishment of more complicated control functions. The following changes in the control system have become necessary:

1. Provide a multiplexed analog system which transmits steering currents, pulsed quad currents, and other signals on the data channel now used for log Q.

2. Increase system capacity by subdividing existing relay tree and status channels.

3. Introduce quasi-parallel operation of the relay tree by speeding up its response, possibly through the use of solid state circuits.

4. Investigate changing the logic of the pattern generator so that beam patterns are transmitted the length of the accelerator, and moving the actual latching circuits (which select beam patterns for a given sector or for a given pulsed steering level) which should be located in the sector alcove rather than in CCR. These improvements will allow an increase in the number of controls, patterns, and analog and status monitoring signals without increasing the amount of wire needed between CCR and the gallery. They also reduce the number of interfacing systems required between the PDP9 and the accelerator.

Recent Changes

1. Pulsed steering and pulsed quadrupole power supplies were installed as follows:

Sector 28	Pulsed Quadrupole Power Supplies	August, 1969	
	Pulsed Steering Power Supplies	September, 1969	
Sector 25	Pulsed Steering Power Supplies	December, 1969	

The pulsed steering power supplies replaced the existing dc steering power supplies, while the pulsed quadrupole power supplies were installed in addition to the existing dc quadrupole supplies. The installed units are designed for six-level operation, but presently are connected for two-level operation. This matches the situation of the pulsed devices in sector 11 and, therefore, the existing two level controls could be extended to the newly installed units. The pulsed steering power supplies have a six-level capability and will deliver a peak current ranging from -8A to +8A. The pulsed quadrupole power supply furnishes a current pulse having a half-sinusoidal shape and a peak amplitude of 60A. The current pulse is time shifted with respect to beam time so that the actual magnet current at beam time may be set to any value from 0 to 60A. Three new pulsed quadrupole power supplies are being built at SLAC. The first one is due to be installed in January, 1970. These new supplies are more compact than the prototype and feature all solid state circuitry.

2. A prototype pulsed analog transmission system is presently being checked out from sector 28. A selector switch is provided in CCR which permits the selection of the following inputs from sector 28: log Q, horizontal steering, vertical

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steering, quadrupole. No means are provided yet to eliminate the log Q signals from other sectors, when the steering or quadrupole currents from sector 28 are viewed.

3. The quadrupole power supply selectors in sectors 1, 2, and 6 were modified to prevent stalling in the homing positions, which could happen when the stepping control from CCR was released too fast. This job was completed in December, 1969.

4. The on-off control of the BAS I (40') quadrupole power supply has been removed. This was the only quadrupole power supply control that had not been removed.

5. Some time was devoted to the study of the problems arising from the planned six-level operation at the pulsed power supplies. In particular, methods for control level selection, up/down control from CCR, pattern distribution, and switching were investigated.

Beam Loading

Work has been started on the beam loading delay problems:

1. Occurrence of false Panofsky long ion chamber (PLIC) pulses when beam loading delay of a high-current beam is changed in the first few sectors, caused by some combination of contact bounce, race conditions, and too slow operation in the beam loading delay relays in the sector trigger generators;

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2. Too large an increment in the beam loading delay setting; and

3. Inability to change the beam loading delay of one beam in any sector without affecting other beams in the same sector.

The tentative solution for (1) and (2) is to provide continuous instead of stepwise variation of the beam loading delay in the sector trigger generators. That for (3) is to provide separate delay for as many as six beams in each sector, individually controllable from CCR, with circuitry capable of identifying the different beams and inserting the correct delay on a pulse-to-pulse basis.

A prototype delay module for verifying that continuous variation will solve problems (1) and (2) is being constructed. If the prototype implements solutions (1) and (2) satisfactorily, changes will be made in the sector trigger generators and in CCR to implement solution (3).

Profile Monitors

A TV profile monitor was installed at girder 4-9. Other profile monitors now exist at the injector, and at girders 1-9, 11-3, and 19-9.

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Klystron Steering Tests

Some tests were made on an idea to reduce the rf steering effect which is observed when certain klystrons recycle. Sets of steering dipoles were installed near the midpoints of two accelerating sections which have the rf steering effect. This change did not result in a satisfactory correction. The next test will be done with two sets of dipoles installed at each end of one 40-foot section. It will be possible to operate these dipoles on a pulse-to-pulse basis.

B. The CCR Computer - A General Summary

The CCR computer is at present being used largely for data logging. Programs for klystron replacement and accelerator quadrupole setting are now being used by the CCR operators. A small amount of computer time goes to testing of the machine protection (Tone Interrupt Unit) circuits with a similar program soon to be available for the personnel protection system.

Plans for the immediate future include augmenting the logging program, upgrading of the klystron replacement and quad setting programs, and a series of test programs to check the computer-accelerator interfaces. The present 8 K memory is becoming a restriction; to alleviate the problem, a software handler is being written to allow program and/or data interchange with the disk.

Since the recent DAB/CCR control room reorganization decision, some concrete plans on how to integrate the two control room computers are being made. The plans envision the DAB (Data Assembly Building) system to be mostly involved with the man/computer interface (command interpreter, scopes, push button handlers) and the CCR (Central Control Room) system to concentrate on the accelerator/computer interface. A data link will connect the two control room computers which will require only moderate data rates, over which will pass high level commands such as "SET BEAM LINE 1 TO 10 GEV." Compressed accelerator data for scope display (refreshed every 2 seconds) will go to the DAB. Continuous logging is desirable during operation, with a great deal of data coming into the computer from the accelerator. Now that the klystron replacement program has become accepted, it is relied upon to operate uninterruptedly. On the other hand there are programs, such as the quad setting program, which are used for a short time, and relatively infrequently. Even now, at this early stage, the 8 K memory is not large enough to store the logging, klystron replacement, and quad setting programs at the same time. Consequently, it will be necessary to have access to the disk.

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To date, we have been limited to the DEC software in using the disk. While this software is quite sophisticated, it was designed for general usage, to meet the needs of a great variety of users. In our case, the DEC software is not compatible with on-line operation.

Work is continuing on the new operating system for the PDP9. The specifications for this system include: a disk monitor which will roll-in programs as needed into dynamically chosen areas of core memory; a timed sequence scheduler which will force delays (at user-assigned points in the program) which allow relays to close and analog signals to become available; and a storage management scheme which permits a degree of reentrance of subroutines.

The logging program is still quite primitive, and should be expanded considerably. A log is printed out at intervals which summarizes a chosen group of failures and malfunctions. The present klystron/modulator recycle log is an example. The summary is printed out at eight hour intervals (or on call), and is used daily by the maintenance groups to indicate those modulator/klystron systems that have shown a high number of faults. With direct access to the disk, other systems with lower fault rates can be logged, and the summary printouts made available at much longer intervals. The present logging program is capable of being easily and rapidly expanded to other systems as desired.

The use of the CCR computer as an aid to operator control of the accelerator has so far been minimal. There are only a few places where open-loop control is of use. The protection circuit checkout is an example of a simple closed-loop control. Future accelerator control systems will be more sophisticated, requiring the computer to make control changes in response to variations in its inputs. Initial attempts will have the operator set up a beam to given parameters, and then let the computer attempt to hold one or more of the parameters constant. An ultimate goal would be to have the computer set up the beam to conform to requested parameters. One of the first attempts at closed-loop control will be the extension of klystron replacement to take place in the interpulse period of 2.7 milliseconds. This requires spectrum input signals from DAB and computer control of the sector 28 klystrons. A logical extension of this control is fine energy control, where sector 27 klystrons would be controlled by the computer. Other possibilities include computer control of steering (requiring beam position inputs), maximization of beam transmission, and maintenance of integrated Q and/or pulse shape of the analyzed beam.

A solid-state addition to the relay tree has been proposed, which will receive and remember a command from the computer and actuate the relay tree for a pre-determined time without requiring the computer interface to continue holding the command signal. This would allow the computer to initiate commands in other sectors during the 100 msec required for execution of the first command. Thus, a command which should be executed "simultaneously" in all sectors can be initiated successively in every sector just as quickly as the computer can load a command into the local memory and receive an acknowledgement. At present, the transmitting circuits in CCR contain several relays which are too slow to transmit different signals within 2 msec of each other. If this time is less than 2 msec, then the computer could address one sector per beam pulse and all 30 sectors in about 100 msec. Only when all 30 sectors have a sector memory, however, can these circuits be speeded up.

Hardware

<u>Sector Memory</u>. A prototype sector memory unit has been built and installed in sector 16 which receives a computer command via the remote control system. A fast storage memory remembers the command if the equipment is not busy. An acknowledgement signal is sent to CCR when the command is stored. Other control signals to that sector are disconnected and then the stored command is executed by the remote control receiver. A command is executed for 0.1 sec and turned off unless the same command is received again in which case execution is extended for an additional 0.1 sec. If a different command signal is sent before completion of the initial command, the new signal is ignored.

The prototype was constructed using discrete components. A second prototype is now being built using integrated circuits, which will reduce the cost by about 50%.

<u>Direct Display</u>. A direct display is becoming a necessity at the accelerator control console. Recently, a T.V. monitor which displays the teletype printer has been set up to enable the operator to interpret the computer responses. This is an improvement but it can only be considered a temporary expedient because the monitor interferes with use of the teletype. The teletype should be reserved for printing information that is to be retained, while the control console display must show all information of immediate interest to the operator. A small keyboard at the console would be a necessary adjunct to this visual display. The operators could then request the computer to send specific displays to the console.

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Log Q, X, Y Interface. A log Q channel interface has been designed for the PDP9. This device will accept selected analog signal from each sector, digitize them and input these signal to the computer via the Direct Memory Access channel on a pulse-to-pulse basis. This input channel operates on a cycle-stealing basis and therefore is able to load the memory without disturbing the operating program. Input signal selection will initially be made by means of a manual switch. This function will eventually be under computer control.

A relay operated "pulse stretcher" circuit was installed in sector 2. With this circuit it is possible for the computer to adjust all four sector 2 quadrupole power supplies at once. Additional circuits, installed in other sectors, would make it possible to adjust many quads simultaneously.

Some difficulties were encountered with common mode voltage in the circuits which bring the quad analogs to the computer A/D converter. Ground connections were corrected at some of the controllers along the gallery.

During this period, some status signals originating in CCR have been connected to the PDP9. These signals describe the states of some of the machine and personnel protection units in CCR, and can be used for a future computercontrolled automatic check of the personnel protection system.

<u>DAB Status Signals</u>. The status monitoring system bringing DAB signals to CCR was connected to the CCR computer. In the process, the number of channels in use was reduced to make this system compatible with the systems serving the accelerator.

When the main trigger failed and was reapplied about half of the sector status transmitters would not resynch properly. This caused the computer to ignore status inputs from those sectors. Three components were added to the bit synch generator in each sector to correct this problem. These faults have since disappeared.

An interface has been designed to input the six beam line patterns to the computer. Programming will enable the computer to assign status changes to a particular beam line.

A new 12-bit ADC has been installed in the analog interface, which produces an output in one μ sec. The four additional bits will allow the computer to read analog signals to a greater precision.

C. Central Control Room

As the average number and operational complexity of electron and positron beams increases, the requirements for oscilloscopes of different kinds in CCR have increased. In studying these problems, we have established the need for modification in the SLAC-built programmed oscilloscope system. The study is now in progress.

The cable trays on the second floor of CCR were rearranged to provide 7 feet of head clearance in most places.

Equipment was installed for controlling the "gulch filler." This equipment makes it possible to deliver short **r**f power pulses to two 40-foot accelerating sections in sector 27. By varying length, timing, and rf phase of these pulses, it is sometimes possible to do a much better job of beam loading compensation.

Many additional alarm signals, mostly originating in the injector area, were connected to the annunciator system in CCR.

One aim of the recent console rearrangement and other planned improvements is to provide two independent control positions in CCR, corresponding to the arrangement in DAB. Each CCR operator will then communicate mostly with his opposite number in DAB and with the experimenters to which he is assigned. It is hoped that this will improve efficiency by increasing the audible-signal-to-noise ratio. In the rearrangement, the left hand, or "maintenance" console was moved to the right, so that there is now only one relatively narrow U-shaped console. The height was built up, and important instruments from the back-up console were installed in the newly compacted array. Certain duplicate panels will be built and installed so that each operator will have easy access to essential beam controls.

Four high quality and two ordinary (RG214/U) video cables were installed to transmit pulse signals between DAB and CCR. Recent experiments have furnished an increasing number of video signals to CCR as an aid in tuning and maintaining useful beams.

Difficulty has occasionally been experienced when it was necessary to change over from the CCR 24 V battery charger to a standby charger. Improvements were made to prevent a recurrence of these difficulties, and to provide for better monitoring of the system.

Video Repeater

A study of the video repeater systems has been made to determine why the risetime has degraded. Design improvements have been recommended and chassis

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modifications are now being made. A maintenance/tuning procedure has been written. A risetime test will be made when modifications are complete.

D. Positron Source and Injector

Positron Source

The Wand-Wheel Protection System was extended by the addition of an ion chamber. The added protection is effective for positron and electron beams. The ion chamber supplements the PLIC System which is less effective in sector 11 due to the heavy shielding from the positron solenoids. This installation was completed in July, 1969. This system was later modified to limit beam power losses in sector 11 to the following values:

5 kW loss for all targets out or wand in

30 kW loss for wheel in and stationary

150 kW loss for wheel in and rotating

Signals corresponding to these power levels come from an ion chamber in the housing and are fed into a control unit. In order to close the circuit into the Tone Interrupt Unit (TIU), a selector switch on the unit has to be set to the power level corresponding to the target in use. This job was completed in December, 1969.

A new PLIC ion chamber system has been installed to protect positron targets and the accelerator waveguide just downstream from the positron source. Provision has been made for electron only operations, as well as for wand, fixed wheel, and moving wheel operation.

Injector

An "off-axis" gun was installed in the injector in December, 1969. This resulted in considerable changes in the I/C control and monitoring signals, at both CCR and the injector. In the present installations, the "Alpha" magnet, which bends the electron beam from the "off-axis" gun into the accelerator, is dc operated, hence, only one of the two existing guns can operate at a time. This fact is reflected in the control and analog signals provided to CCR.

The problem of how to control two gun modulators from two CCR operating positions was studied in conjunction with the injector group and concepts for control panel layouts were defined.

The transmission of analog and control signals between the injector and CCR is being reviewed in order to make better use of the existing transmission facilities. This is necessary so that future needs can be met without increasing these facilities. Some of the inefficiency is due to the fact that many of the transmitted analog signals (in some cases up to 18) share a common meter in CCR. Solutions are aimed at doing the switching at the injector, thus freeing wire pairs in the long haul cable. Similarly, a saving in relay tree assignments may be possible for the gun modulator control signals, when the particular features of the gun control panel are considered.

E. Personnel and Machine Protection

Recent Personnel Protection System (PPS) Changes

The Personnel Protection racks for end station A and B (located in DAB) were completely rebuilt using modular packaging. In addition, all beam shutoff ion chambers were calibrated and set to trip at 100 mr. The analog signals were adjusted to read within 5% at the DAB console. DAB circuitry has been further modified so that if the BSY or end stations are open and a beam shutoff ion chamber is tripped or removed, the magnet, slits and stoppers can be operated. This change was made to enable testing of these systems during downtime.

Three beam shutoff ion chambers were removed from the east wall of end station B and installed on the CE-53 beam line. The door to the end station B target room has been upgraded so that it is now under full control of the DAB operators.

A number of radiation stop circuits in the research area were moved to accommodate the experimental program changes. Circuit changes were made along the accelerator gallery so that tone loop checks could be performed using the keybank release control in CCR to break the loop at a designated sector. This change was necessary because tunnel access is limited to every other sector. In addition, a tunnel gate in sector 11 at girder 11-7 was connected to the PPS so that only a limited area need be searched after personnel had left the positron area. Machine Protection System

A beam stopper associated with BAS II operation had on occasion been accidentally exposed to the beam. In order to prevent material damage and personnel hazard, since the stopper is part of the PPS, a temperature monitor was installed. A thermocouple in the stopper operates a meter relay in the gallery. When a preset temperature is exceeded, the beam is shut off. The job was completed in September, 1969.

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F. Trigger System

Recent Improvements

With the installation of the new gun modulator, many features of the injector trigger generator became redundant, e.g., the L and H triggers and their associated control and analog signals. A new injector trigger generator (ITG) was installed and went into operation in September, 1969.

The synchronization of the master trigger generator with the master oscillator was completed and went into operation at the end of October, 1969.

VIII. PUBLICATIONS

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SLAC-PUB-622

NEUTRON-PROTON ELASTIC SCATTERING FROM 2 to 7 GeV/c. M. L. Perl, J. Cox (SLAC); M. J. Longo (Michigan); M. N. Kreisler (Princeton). Submitted to Physical Review.

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COMPUTATION OF THE FAST WALSH-FOURIER TRANSFORM. K. W. Henderson. Submitted to IEEE Trans. on Computers.

SLAC-PUB-644

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SLAC-PUB-645

A THEORY OF DEEP INELASTIC LEPTON-NUCLEON SCATTERING AND LEPTON PAIR ANNIHILATION PROC-ESSES. II. DEEP INELASTIC ELECTRON SCATTERING. S. D. Drell, D. J. Levy, T.-M. Yan. Submitted to Physical Review.

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REGGE ANALYSIS OF π^{0} AND π^{+} PHOTOPRODUCTION AT BACKWARD ANGLES. J. V. Beaupre, E. A. Paschos. Submitted to Phys. Rev.

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SLAC-PUB-661

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SLAC-PUB-662

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SLAC-PUB-672

GRAPH-THEORETICAL METHODS FOR DETECTING AND DESCRIBING GESTALT CLUSTERS. C. T. Zahn. Submitted to IEEE Trans. Comput.

SLAC-PUB-678

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SLAC-PUB-680

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SLAC-PUB-681

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SLAC-PUB-682

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SLAC-PUB-683

ON THE ANALYSIS OF VECTOR MESON PRODUCTION BY POLARIZED PHOTONS. K. Schilling (Cal Tech); P. Seyboth, G. Wolf (SLAC). To be submitted to Nucl. Phys.

SLAC-PUB-684

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SLAC-PUB-685

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SLAC-PUB-688

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SLAC-PUB-690

PHOTOPRODUCTION OF THE A₂ MESON IN THE REACTION $\gamma p \rightarrow n\pi^+ \pi^+ \pi^-$ AND AN ESTIMATE OF THE A₂ $\gamma \pi$ WIDTH. Y. Eisenberg, B. Haber, B. Horovitz, E. Peleg, E. E. Ronat, A. Shapira, G. Vishinsky, G. Yekutieli (Weizmann Inst.); J. Ballam, G. B. Chadwick, Z. G. T. Guiragossián, A. Levy, M. Menke, P. Seyboth, G. Wolf (SLAC). Phys. Rev. Lett. 23: 1322-4, 1969.

SLAC-PUB-692

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SLAC-PUB-697

FORWARD COMPTON SCATTERING. M. Damashek, F. J. Gilman. Submitted for publication.

SLAC-PUB-698

SLAC-POB-030 MEASUREMENT OF THE RATIO OF THE PROTON FORM FACTORS, G_E/G_M , AT HIGH MOMENTUM TRANSFERS AND THE QUESTION OF SCALING. J. Litt, G. Buschhorn, D. H. Coward, H. DeStaebler, L. W. Mo, R. E. Taylor (SLAC); B. C. Barish, S. C. Loken, J. Pine (Cal Tech); J. I. Friedman, G. C. Hartmann, H. W. Kendall (MIT, LNS). Submitted to Phys. Lett. B.

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SLAC-PUB-673

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SLAC-PUB-687

SLAC-LRL MUON SPECTROMETER. R. De Coster, S. Flatté, M. L. Stevenson (UCRL, Berkeley); W. T. Toner, T. F. Zipf (SLAC). Presented at 11th Int. Conf. on Cosmic Ray Physics, Budapest, Hungary, Aug 24-Sep 5, 1969.

SLAC-PUB-677

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SLAC-PUB-674

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SLAC-PUB-676

STATUS OF QUANTUM ELECTRODYNAMICS. S. J. Brodsky. Invited talk presented at Int. Symposium on Electron and Photon Interactions at High Energies, Liverpool, Sep 14-20, 1969.

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SLAC-106

40-INCH HYDROGEN BUBBLE CHAMBER CONVERSION TO 70 KILOGAUSS SUPERCONDUCTING MAGNET; PROPOSAL III. J. Alcorn, J. Ballam, R. Blumberg, H. Brechna, H. Petersen, A. Rogers, S. St. Lorant, K. Skarpaas, B. Sukiennicki.

SLAC-110

QUARTERLY STATUS REPORT, April 1 to June 30, 1969.

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